STEREO Requirements

A. Santo

Pre-phase A Deliverables

- Project
  - Pre-phase A report due Nov 30
    - Mission design, spacecraft design, ground system and integration and operations concept
    - Spacecraft-to-instrument interface description
    - Schedule and cost estimate
- Subsystem Leads
  - Monthly status report of 1/4 to 1/2 page
  - Design documented in status review viewgraphs and text pages
  - Design write-up for Pre-phase A report of approximately 5 pages
  - Cost estimate for 2002 and 2004 launches
  - 2002 schedule to detail of about 10 line items

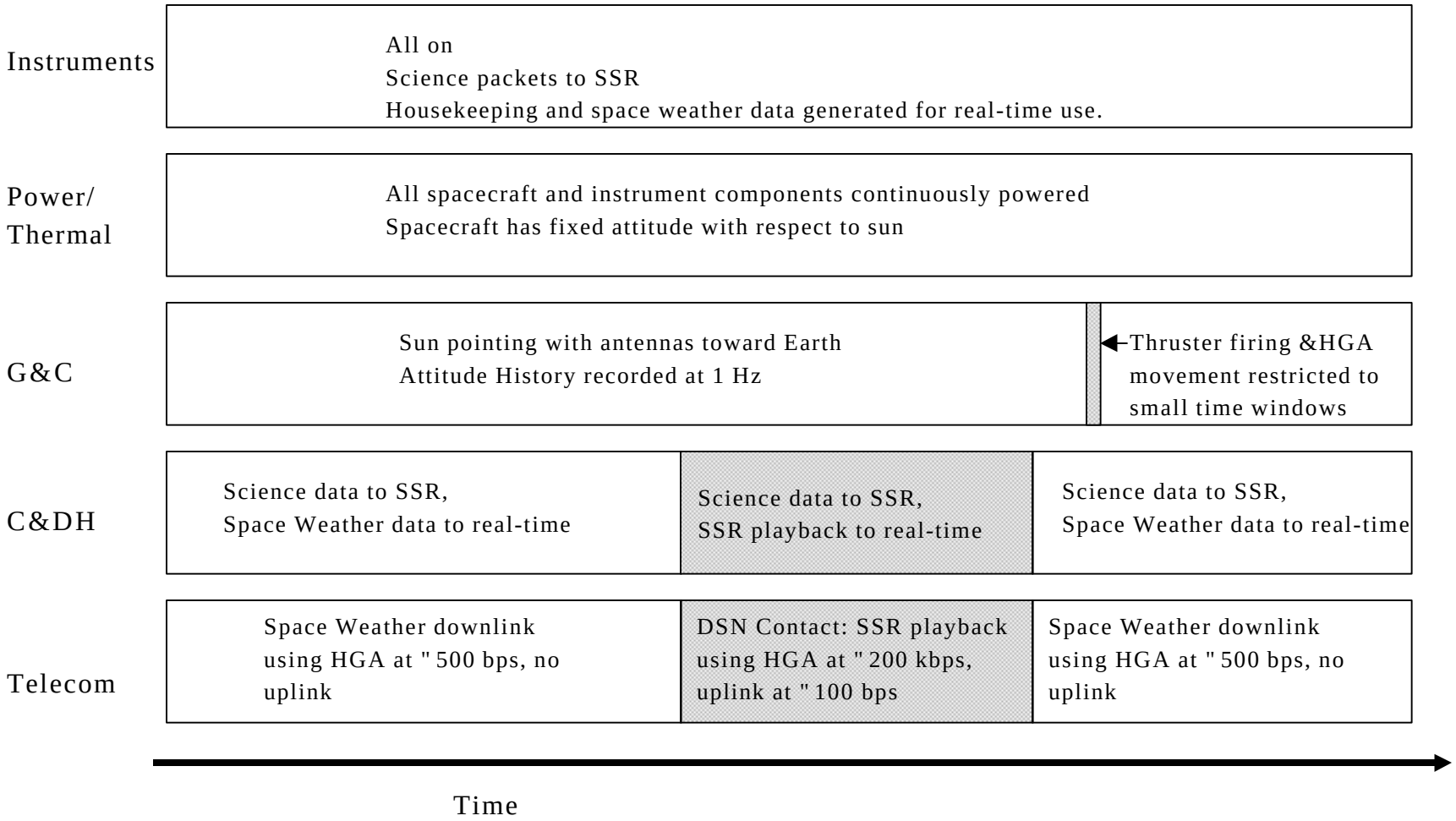
Subsystem Leads

• Mission Design/Navigation	Peter Sharer
• Propulsion/Launch Vehicle	Larry Mosher
• Mechanical	Mike Kreitz
• Structure	Terry Betenbaugh
• Thermal	Jeff Maynard
• C&DH	Dan Rodriquez
• Power	Jay Jenkins
• Telecommunication	Judi VonMehlem
• G&C	Courtney Ray
• Software	Ben Ballard
• Product Assurance	Ed Goss
• Instrument Interface	John Boldt
• Ground System/I&T/Ops	Glen Baer

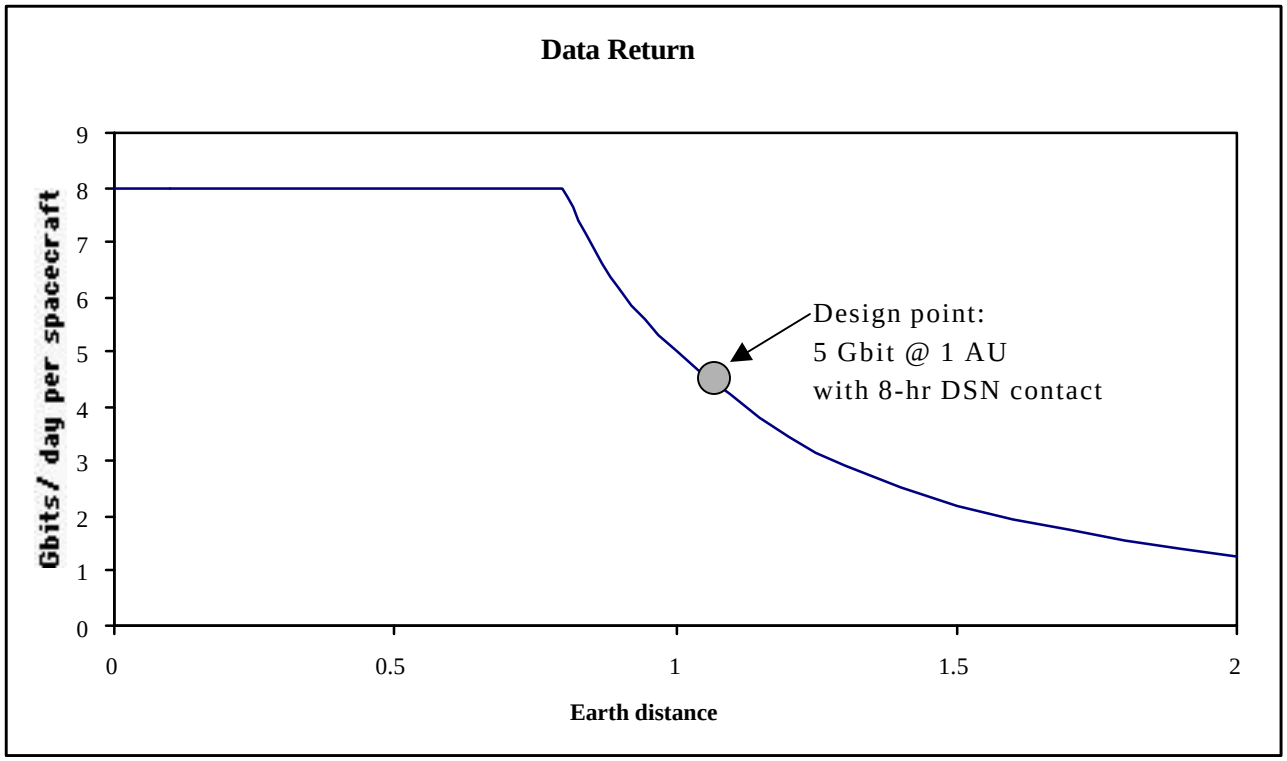
Instrument Operations Concept

- Instrument operation including health monitoring is a GSFC responsibility, spacecraft operations is an APL responsibility
- Science team (GSFC) should not need to know any of the details of spacecraft operation to plan instrument activity
  - Small time windows budgeted for HGA movement and propulsive events
  - Instrument activity independent of downlink schedule
  - Stored-command memory budgeted for instrument operations
- Spacecraft has resources (power, data bandwidth) to support all instrument activity simultaneously with the only limitation being data volume

Operations Concept



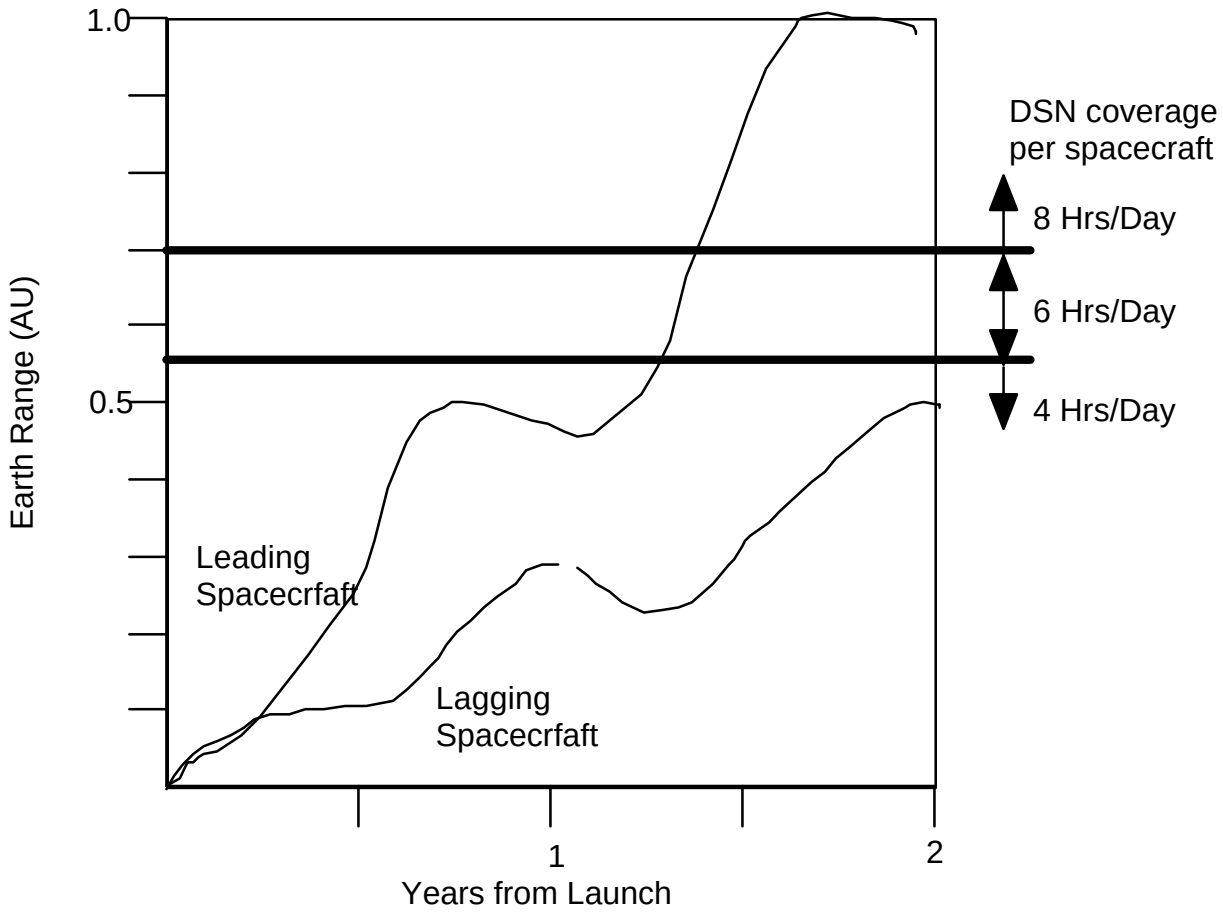
Data Return and DSN Coverage



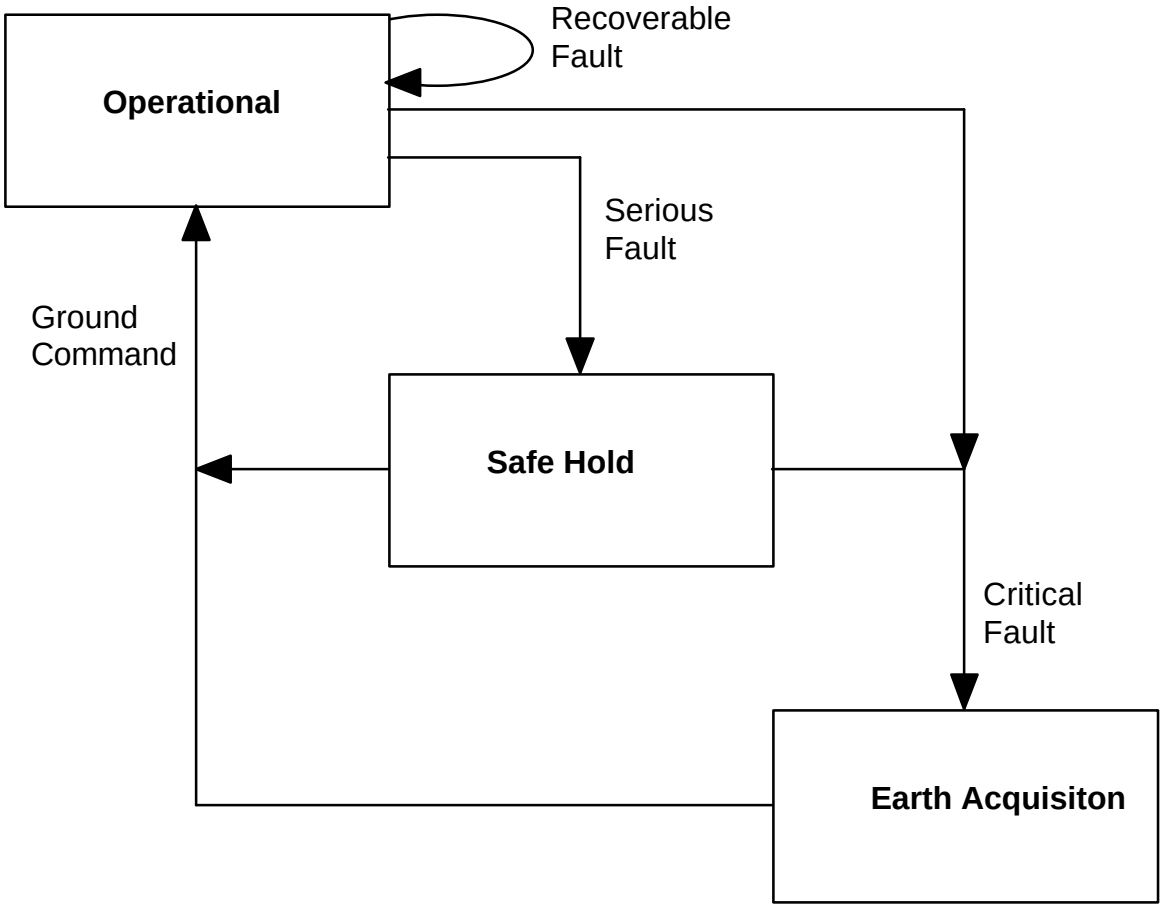
DSN Coverage per spacecraft

Distance(AU)	Hrs/Day
0-0.56	4
0.56-0.7	6
0.7-2.0	8

DSN Coverage Timeline



State Diagram



Operational

- Enabled time-tag commands
- All instruments on
- Sun point with all antennas toward Earth
- Telecom over HGA

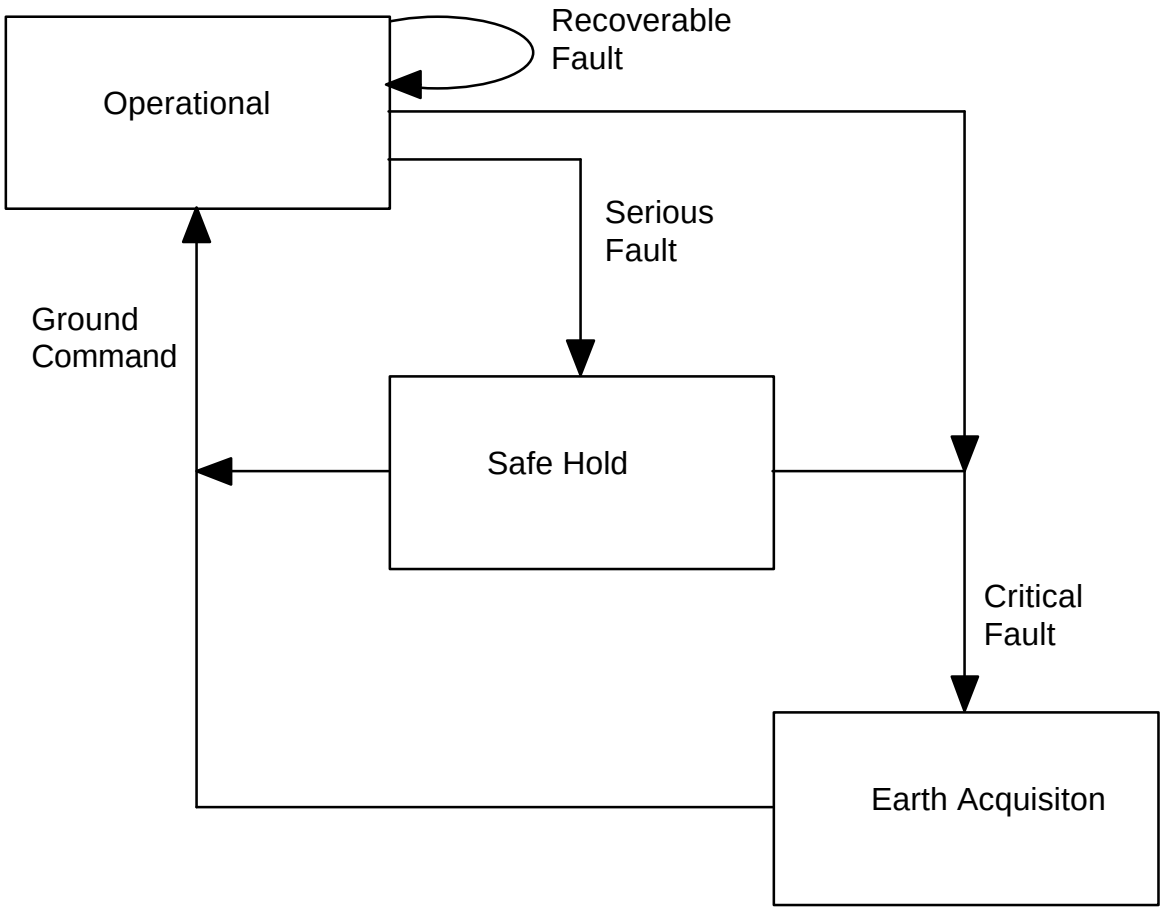
Safe Hold
(Roll-axis knowledge of assumed)

- Suspend time-tag commands
- Reset spacecraft state (instruments off)
- Sun point with antennas at Earth
- Telecom emergency rates over MGA

Earth Acquisition
(Roll-axis knowledge not assumed)

- Suspend time-tag commands
- Reset spacecraft state (instruments off)
- Sun point and rotate 1 deg per minute
- Telecom emergency rates over MGA
- Recovery initiated with a stop-rotate command

Fault-Protection Description



Recoverable Fault

- Instrument fault
- Configuration error

Serious Fault

- C&DH/G&C reset
- Unexpected battery discharge
- G&C component failure
- G&C health check violation
  - Sun-keep-in
  - Thruster use
  - Orbit span

Critical Fault

- Expiration of command loss timer
- Low bus voltage
- Loss of UT
- Multiple G&C health check violations

Mechanical Requirements

- Deployables and Mechanisms
  - Two Solar array panels
  - Magnetometer boom
  - Radio burst tracker has 3 wire antennas
  - HGA gimbal
- Center-of-pressure to center-of-mass offset < 10 cm along Sun line
- Instrument accommodation:

Instrument	Orientation	Field-of-View
EPD	45° off Sun line	N/A
HI	90° off Sun line, Earth Pointing	165° x 165°
Mag	Anti-Sun line	N/A
RBT	Orthogonal	N/A
SCIP	Sun pointing	10° x 10°
SWPA	One cup at Sun, other 90° off Sun	45° half-cone

G&C Performance Requirements

- Spacecraft pointing - 3 sigma (using SCIP error signal good to 0.1 arcsec once instrument boresight is within 5 arcmin of Sun)
  - Knowledge: roll- 20 arcsec, pitch/yaw- 0.1 arcsec
  - Performance: roll- 0.1 degree, pitch/yaw- 20 arcsec
  - Low frequency drift: roll- 1 arcsec/second, pitch/yaw- none
  - Jitter: roll- 30 arcsec RMS, pitch/yaw- 1.5 arcsec (0.1 to TBD Hz)

    (Note that the pointing requirements are only for the SCIP)
- Momentum storage capacity > 4 days in operational mode (instruments may want to close covers prior to thruster firing)
- Nominal HGA pointing to 0.1°, 1° while thrusting
- Time tagged attitude samples to within 0.1 sec accuracy as supplied by C&DH

G&C Functional Requirements

- Should not require ground commanding for normal operation
- Autonomous HGA gimbal and momentum management control (operational control restricted to small time windows)
- Telemetry
  - Continuous 1 Hz UT stamped attitude data to recorder, each sample < 400 bits
  - Attitude history data should not need ground processing, all corrections and calibrations done on-board
  - Automatically record all thruster data
  - Automatically record diagnostic data on entry to a safe mode
  - Have ability to record at least 60 seconds of continuous high-rate data (gyro, error signal,star tracker, and RWA data) to evaluate jitter performance
- Store on-board 2 software images (or provide other method) to allow for software upgrade capability

G&C Safing Requirements

- Provide an safe-hold attitude where the Z-axis is controlled to within 1 ° of the Sun, MGA within 1 ° of Earth
- Provide a Earth-acquisition attitude where the Z-axis axis is controlled to within 1 ° of the Sun rotation about the Sun line is controlled to within 30 seconds per revolution
- Provide an autonomous Sun-keep-in capability where the Sun angle is programmable
- Return to < 5 degrees of sun pointing in < 12 minutes from any attitude after entry into a safe mode

Guidance Requirements

- On-board orbit propagation to allow autonomous pointing of HGA when Earth distance > 1E6 km
- Pointing scenarios
  - Sun pointing with HGA/MGA at Earth with and without instrument error signal
  - Solar pressure momentum bias with max sun-angle limit
  - Generic pointing capability

Thruster Control Requirements

- Closed-loop control of momentum dumps
  - No ground commands for thruster selection, firing duration
  - Support emergency momentum control
    - Autonomous attitude acquisition after launch vehicle separation
    - Autonomous momentum dump when near control limit
  - Support operational momentum control to target momentum state
- Maintain HGA pointing during operational thruster firings
- Complete autonomous thruster firings within 300 seconds
- Provide a method to manually send commands during I&T to control all of the propulsion valves and thrusters that are controlled by the G&C

Propulsion Requirements

- Propellant for 5 year mission
  - Include detumble and operational momentum management
  - No ? V or orbit maintenance requirement
- Telemetry for propellant estimation to 5% accuracy
- Thruster geometry to enable a 3-axis desat while HGA earth pointing
- Minimum torque per pulse per axis < 0.25 momentum storage capability per axis

C&DH Requirements-1

- CCSDS uplink/downlink compatible
- 8 Gbit recorder w/simultaneous playback, record
- UT maintenance & distribution to 0.1 sec accuracy
- Support science data collection
  - Allow instruments to generate their max data rate simultaneously
    - EPD - 0.2 kbps
    - Mag - 0.2 kbps
    - RBT - 0.2 kbps
    - SWPA - 0.2 kbps
    - HI - 7 kbps
    - SCIP - 400 kbps
  - Allow variable instrument bandwidth allocation
  - Support a real-time science downlink capability

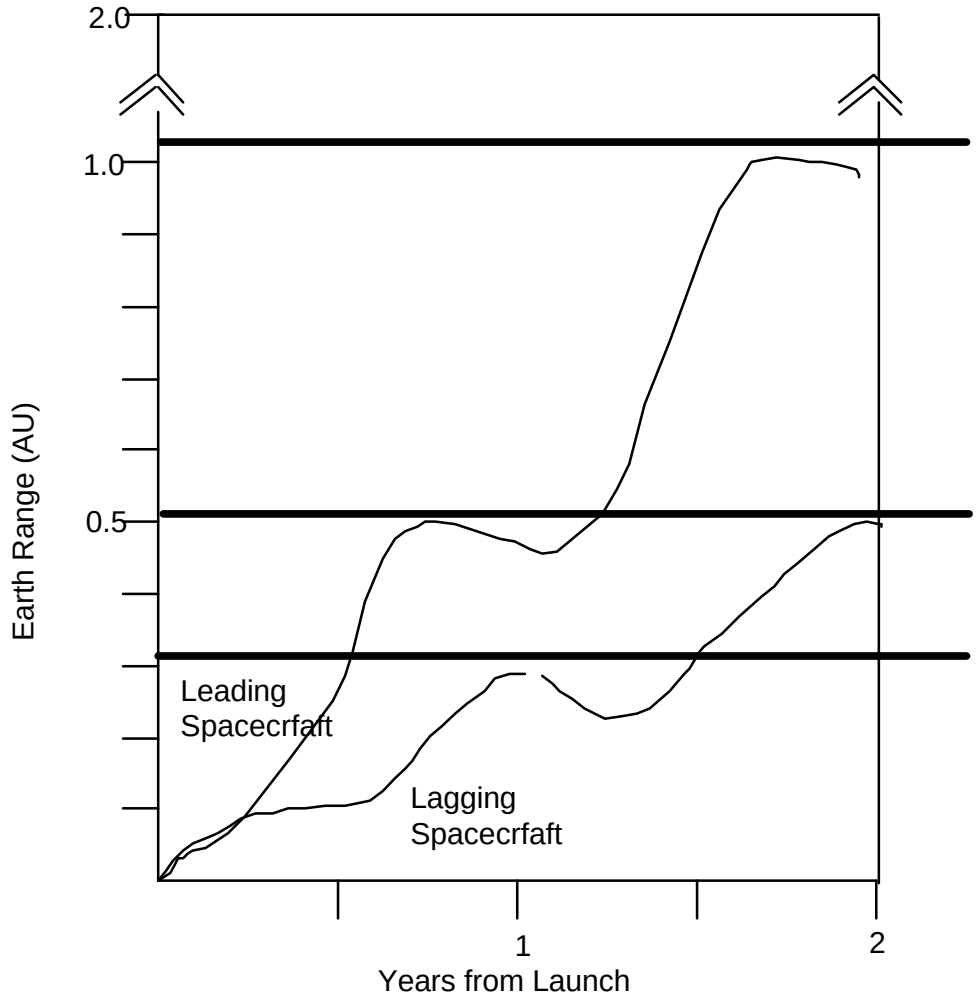
C&DH Requirements-2

- Label science and attitude history packets in a manner so they can be identified and routed to GSFC without inspection
- During data playback the downlink should have a recorder playback content >97%
- No C&DH data compression is required
- Store on-board 2 software images (or provide other method) to allow for software upgrade capability

C&DH Requirements-3

- Provide for two uplink data rates " 100 bps and 7 bps
- Provide multiple downlink rates
  - High-rate science
    - HGA link to DSN 34-m over 0 to 2 AU using RS+6:1 convolution coding
    - Max rate set to dump recorder in 4 hr DSN pass (" 3 hrs downlink time)
    - Min rate set by RF link @ 2 AU Earth distance
    - Nominal rate spacing of 3 dB
  - Low-rate science (called ‘Beacon mode’ in Rust Report)
    - HGA downlink to TBD assets
    - RS+2:1 convolution coding and fixed-frame formatting required to keep ground decommutation simple
  - Low-rate engineering
    - Real-time engineering data over LGAs for L+3 days to 34-m DSN
    - Safe-hold attitude and Earth acquisition using MGA over 0-2 AU

Bit Rate Selection Guide



- Bit rates should be selected to optimize the total data return
- Primary bit rate selections (dark lines) should be selected to optimize data return over the mission periods where the s/c range changes little
- Other bit rates (not shown) should be selected to keep the rate separation < 4 dB

Telecom Requirements-1

- Provide simultaneous uplink, downlink, and nav data
- Link margins > 3 dB, BER < 10E-6
- Use DSN 34-m BWG antennas for nominal contacts
- Provide data for navigation to determine spacecraft separation to 1 arcsec
- Power Amplifier to support:
  - 5 Gbit downlink in 8 Hr DSN pass (" 7 hrs downlink) at 1.0 AU Earth distance; space weather is not to be a requirement driver
  - Safe-hold mode and Earth-acquisition mode communications
  - Continuous power amplifier operation over 2 year mission and for extended periods during ground test

Telecom Requirements-2

- Provide antennas to support nominal communications:
  - LGA configuration: A > 1000 bps downlink and nominal (" 100 bps) uplink rate for L+3 days while sun pointing in any roll axis direction using the DSN 34-m BWG antennas.
  - MGA configuration: A > 1000 bps downlink and nominal (" 100 bps) uplink rate for L+3 days to L+20 days while sun pointing with the roll axis Earth pointing (assume no HGA) using the DSN 34-m BWG antennas.
  - HGA configuration: A > 50 kbps downlink and nominal (" 100 bps) uplink rate from L+20 days through solar conjunction for both spacecraft using the DSN 34-m BWG antennas.

Telecom Requirements-3

- Provide MGA(s) to support emergency communications
  - Enable safe-hold mode and Earth-acquisition mode communication over 0-2 AU Earth distance for both spacecraft
  - The narrow-angle beamwidth must support Earth-acquisition detection using a 3-hr rotation rate (about 8 degrees)
  - The wide-angle gain must support uplink > 7 bps and downlink > 10 bps
- Complete subsystem-level DSN compatibility testing before delivery of flight hardware to C&DH

Power Requirements

- Power system
  - Should not require ground commanding for normal operation
  - Allow for solar-only operation with all instruments and subsystems simultaneously powered
  - Fuses for instruments only
- Battery
  - Must not restrict launch window
  - Must support energy profile through launch till first contact +1 hr
  - Support emergency-mode loads for at least 12 minutes after low voltage trip
- Solar array
  - Sized for 2 years operation with all systems powered-- assume maximum off-Sun pointing of 5 degrees
  - Non-gimbaled
  - Should tolerate shadowing without damage

Spacecraft/Instrument Interfaces

- Instrument interface details provided to GSFC for inclusion into instrument AO
- Prediction of pointing performance and data return are key spacecraft parameters needed to optimize instrument design
- Areas where spacecraft design and instrument design overlap need investigation
  - Mag boom length
  - SCIP max-data rate
  - Jitter specification
  - Data return

Ground System Requirements

- Provide an interface to the instruments for command and telemetry during I&T
  - Command interface should support both near-real time and stored commanding
  - Telemetry interface should support real-time health and status data and near-real time science data, (the science data interface can be file based)
- Provide an interface to GSFC for command and telemetry during operations
  - Command interface should support both near-real time and stored commanding
  - Telemetry interface includes housekeeping data, science packets, attitude history packets, time correlation file, and navigation data
  - Telemetry interface should support near-real time data access from a file based system. The time correlation and navigation data sets should include predictive data.
- Provide a method to allow APL operations to identify dropped packets from a recorder playback within 1 hour of data receipt
- After launch assemble the C&DH and the G&C brassboard hardware together with the G&C environmental simulator to form a real-time spacecraft simulator that can be used to verify MOPS command scripts
- Provide cost/benefit trades for providing C&DH emulators to instruments and mini-MOC to subsystem developers

I&T & Operations Requirements

- No non-flight hardware is to be installed on the s/c during I&T
- I&T and Ops to support concurrent development and operation of two spacecraft
- During operations accept near-real-time bent-pipe instrument commands and provide bent-pipe data to GSFC
- Provide GSFC an opportunity for instrument commanding on each DSN pass
- Provide for high-rate data dump on each DSN pass
- Provide a ‘non-standard’ service to schedule and support urgent DSN contacts due to space weather emergencies
- Maintain on each spacecraft the correlation of UT to MET to within 0.5 seconds and provide correlation data to GSFC

Meeting Notes

- Meeting notes on http://sd-www.jhuapl.edu/STEREO/Reports/
- 10/15 meeting agenda
  - L. Mosher — Launch Vehicle Selection
  - P. Sharer — Mission Design
  - M. Kreitz — Mechanical Layout
  - E. Goss — Radiation Requirements

Subsystem Presentations

- Provide a powerpoint file for the www archive
  - Name, date, page on slide footer
  - No logos or other unnecessary graphics wanted-- keep file size small
- Presentation topics include
  - Design Approach
    - Block diagram or system configuration drawings
    - Component summary including mass, power, make/buy, heritage
    - Margin estimates or analysis results
  - Identification of subsystem drivers
  - Trade studies for phase A/B
  - Areas for technology insertion or cost-saving innovation